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VHF RADIO BROADCASTING:

Propagation and diversity reception of mixed polarised signals over a sea path

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VHF RADIO BROADCASTING : PROPAGATION AND DIVERSITY RECEPTION OF MIXED POLARISED SIGNALS OVER A SEA PATH.

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Summary

This Report describes measurements of v.h.f. propagation over a 170 km sea path. Statistical analysis of the results provides information about the correlation between horizontally and vertically polarised field components received from an existing mixed (nominally circularly) polarised v.h.f. transmitting station.

The possibility of using a polarisation diversity reception system, switching between the two field components, for use in low signal level, v.h.f. sea path re-broadcast links, is discussed. It is concluded that polarisation diversity provides no significant advantages.

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VHF RADIO BROADCASTING : PROPAGATION AND DIVERSITY RECEPTION OF MIXED POLARISED SIGNALS OVER A SEA PATH.

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1. INTRODUCTION

Following the changes and new restrictions laid down at the ITU RARC VHF Conference held in Geneva 1984[1], some re-broadcast links, which are already marginal in performance, will become worse. One such link is for the Channel Islands, and incorporates a feed implemented by reception of the Rowridge transmitter on Alderney. Under the new Plan, a reduction in the power radiated towards Alderney will be necessary, and then reception may not be of adequate quality for sufficient periods of time due to fading. However, the new Plan provides for the re-engineering of the v.h.f./f.m. transmitter network from horizontal to mixed polarisisation. (In most cases, transmitting stations re-engineered for mixed polarisation will be nominally circularly polarised, although slant polarisation may be used for low power installations). The addition of the vertically polarised component may provide extra options for reception, namely, either a component diversity system switching between the horizontal and vertical field components, or the reception of circular polarisation.

Both of these options require some knowledge of the fading characteristics of circularly polarised signals over a propagation path of sufficient length and in the case of the Channel Islands, a sea path. If there are large amplitude variations between the horizontal and vertical field components, a simple diversity switch to select the stronger will be a benefit, or if the components have similar amplitude variations, and the (nominally quadrature) phase relationship remains unchanged, a circularly polarised receiving system may be beneficial.

This Report describes an experiment that was conducted to gain information about the propagation of the field components of a circularly polarised signal over a sea path.

2. PRESENT SYSTEM

At present the main v.h.f./f.m. re-broadcast link (RBL) to the Channel Islands is achieved by diversity reception of either North Hessary Tor or Rowridge, at Alderney. Under normal circumstances the system will select North Hessary Tor, receiving Radios 2 and 3 on three 6-element yagi aerials at a height of 4.5 m on the main mast, and Radio 4 on two 6-element yagi aerials at a separate location away from the main mast, selected to give natural screening from a co-channel French station. If the field strength of North Hessary Tor falls below a pre-determined level, whilst that of Rowridge is above, the system will automatically select Rowridge, using three 6-element yagi aerials at a height of 4.5 m to receive Radios 2, 3 and 4. The programmes are fed from Alderney to the transmitting station at Les Platons on a microwave link. Should any part of this system fail, a standby programme feed (RBS) is obtained by direct reception of North Hessary Tor at Les Platons, although decreased signal level demands that the service is broadcast monophonically.

When Rowridge is re-engineered to mixed polarisation and the new ITU restrictions come into force, the field strength at Alderney will decrease by at least 6 dB. The necessary increase in receiving aerial aperture to recover the signal is not attractive and may be impractical, although additional aerial height, or height diversity would be an advantage.

3. EXPERIMENTAL WORK

The signal levels obtained from the horizontal and vertical field components of a circularly polarised v.h.f. transmission were measured and recorded separately over a period of approximately one month.

3.1 Location

In order to reproduce the particular propagation conditions of interest, a careful choice of receiving and transmitting locations was necessary. The requirements for a circularly polarised transmitting station, with a convenient reception point over a sea path of sufficient length, limited the choice of transmitter to either Les Platons or Brighton, with Rowridge as the reception point in both cases.

The Brighton-Rowridge path is mainly coastal, and a little short so it was considered to be less suitable for our purposes. Les Platons-Rowridge is slightly longer than necessary, and possibly more susceptible to interference from other stations, but nevertheless appeared to be a more useful starting point. The locations of these stations are illustrated in Fig. 1.

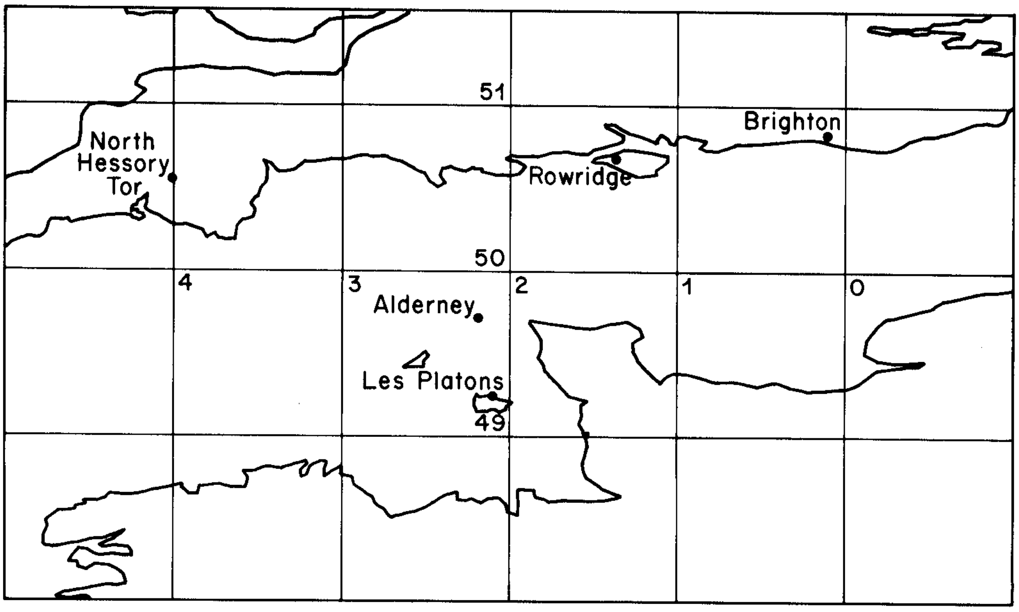


Fig. 1: Map showing the transmitter and receiver locations referred to in the text.

3.2 Equipment

Two 4-element yagi aerials, one vertically polarised and one horizontally polarised were fitted on the mast of the BBC transmitting station at Rowridge, at a height of approximately 130 m above ground level, pointing in the direction of Les Platons (198° ETN). Separate feeders from each aerial ran into the main building. Signals from these were switched alternately via a co-axial relay and fed into a v.h.f. monitoring receiver. The detected levels of each were recorded independently on a dual-trace chart recorder.

As the final accuracy of the analysis of the signal amplitude from the vertical and horizontal field components depends on the discrimination of each aerial to the orthogonal polarisation, field measurements were undertaken. These consisted of transmitting low power, linearly polarised signals towards the aerials at Rowridge, from the direction of Les Platons, at a distance of approximately 3 km. Direct comparison between received signal levels was possible, and cross-polar discriminations of better than 20 dB were measured. These were considered more than adequate for this investigation.

4. RESULTS

The signal levels were recorded on a chart recorder. Each chart contained two plots, the amplitude of the horizontally polarised signal (h) versus time and the amplitude of the vertically polarised signal (v) versus time. Since both components were recorded at the same time, direct investigation of the amplitude correlation between them is possible.

Recordings were made from approximately 6.00 a.m. to 12.00 p.m. (start-up to close-down) for a period of about a month.

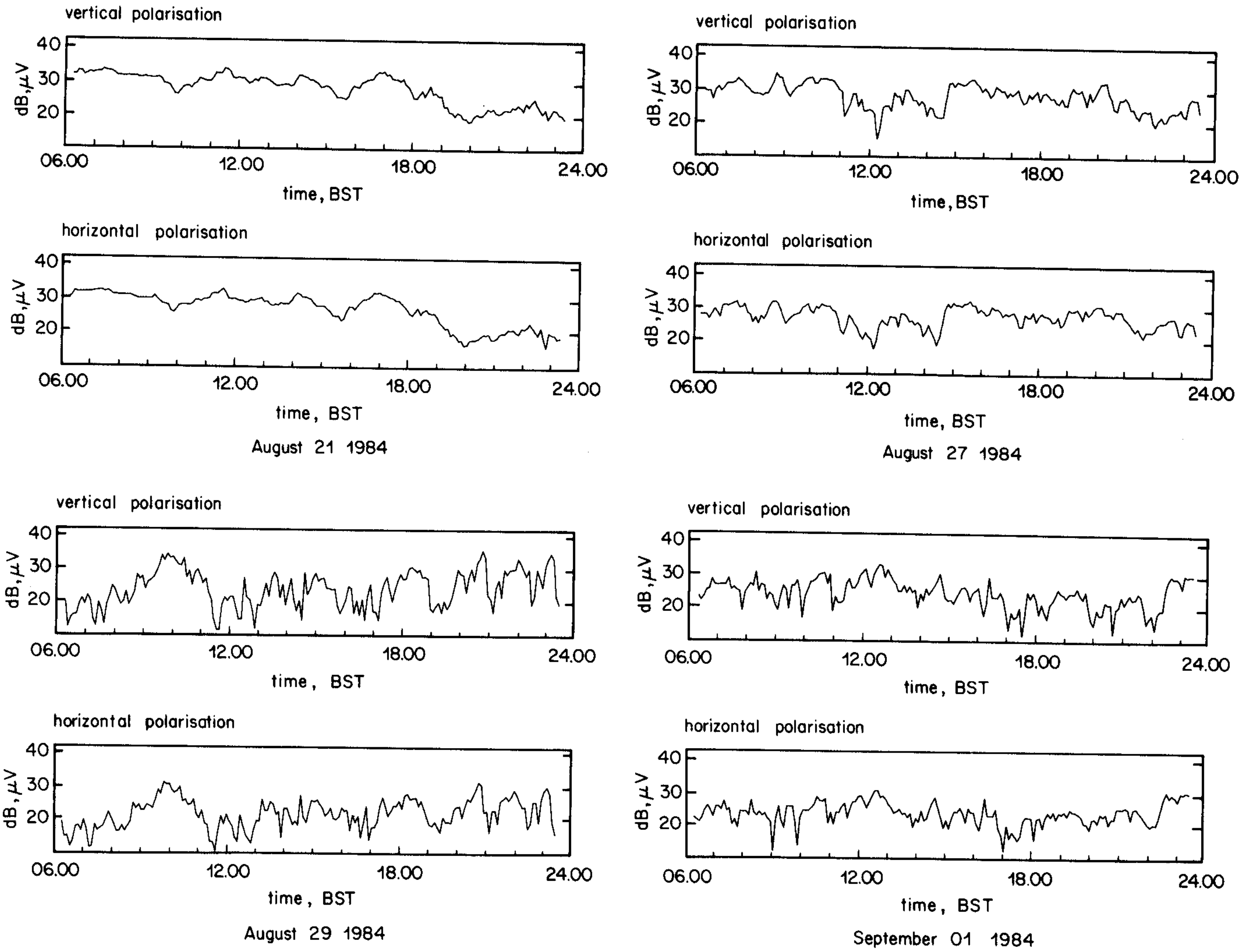
The resulting charts were digitised, values being taken at intervals of 6 minutes, corresponding to 0.1 inch of chart length. The digitised versions were then input to a computer for processing. Fig. 2 shows computer-reduced versions of typical original charts.

Signal level variations exceeding 20 dB, often occurring in relatively short time periods are evident. This form of fading is common over long sea paths. The effect is more easily appreciated from Fig.3a, graphs showing signal level, (dBμV), against the percentage of total recording time each field component fell below this level, and Fig. 3b showing signal level, (dBμV), against the percentage of total recording time both field components fell below the level. The graphs are plotted on linear versus probability axes and near log-normal distributions about the mean are apparent.

4.1 Analysis of Results

If $v(t_1)$, $v(t_2)$ ... $v(t_N)$ are the amplitudes of the vertically polarised field component at times t_1 to t_N, and $h(t_1)$, $h(t_2)$ ... $h(t_N)$ are the amplitudes of the horizontally polarised field components at the same times, the mean values of the components are calculated by:-

$$\bar{v} = \frac{1}{N} \sum_{t=t_1}^{t_N} v(t) \quad \text{and} \quad \bar{h} = \frac{1}{N} \sum_{t=t_1}^{t_N} h(t)$$



August 21 1984

August 27 1984

August 29 1984

September 01 1984

Fig. 2: Received signal levels of each field component at Rowridge on the date shown.

The standard deviations, σ_v and σ_h, are given by:-

$$\sigma_v = \sqrt{\frac{1}{N}\sum_{t=t_1}^{t_N}(v(t)-\bar{v})^2}$$

and

$$\sigma_h = \sqrt{\frac{1}{N}\sum_{t=t_1}^{t_N}(h(t)-\bar{h})^2}$$

And the normalised cross-correlation coefficient, ρ, at zero displacement may be expressed as:-

$$\rho = \frac{1}{N}\sum_{t=t_1}^{t_N}\left(\frac{v(t)-\bar{v}}{\sigma_v}\right)\left(\frac{h(t)-\bar{h}}{\sigma_h}\right)$$

Table 1 shows mean signal level, standard deviation, and correlation coefficient, calculated firstly for each day of recording, and finally for the entire recording period.

5. DISCUSSION

For an ideal dual diversity system, the correlation should be −1[2]. That is, the component variations are perfectly correlated, but when one signal decreases the other increases. This might occur if, for example, the propagation conditions produce polarisation rotation of a linearly polarised signal, an unlikely event in practice. It may be argued that a more likely, advantageous statistical condition would be such that the components are completely un-correlated and the coefficient is 0. Nevertheless, according to Brennan[3] most of the diversity potential will be realised with correlation coefficients up to a value of +0.3, and some useful advantage may be obtained with even higher coefficients.

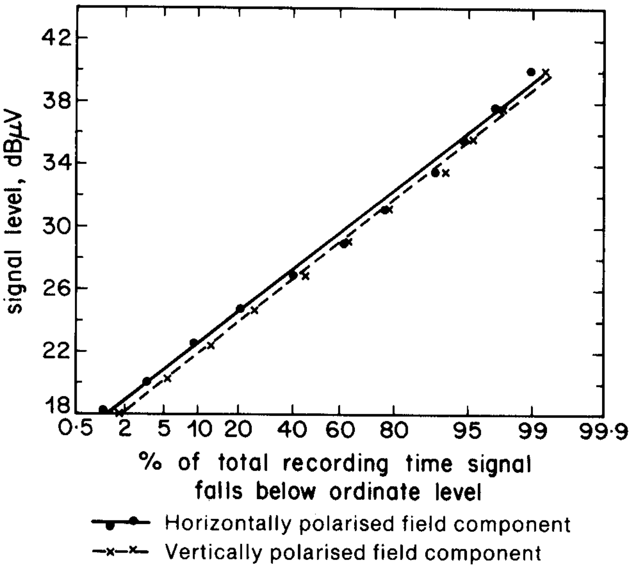


Fig. 3a: Signal level versus percentage of total recording time the signal strength of each field component falls below given value.

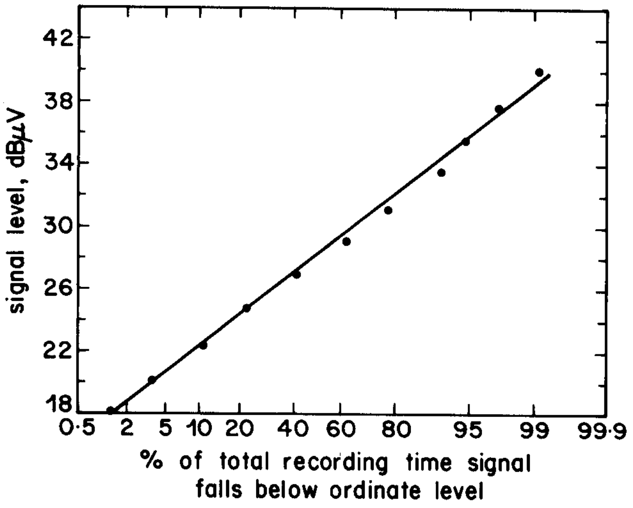


Fig. 3b: Signal level versus percentage of total recording time the signal strengths of both field components fall below given value.

Table 1
Results of Statistical Analysis on Charts

Date of Recording	Mean signal level (dBμV)		Standard Deviation(dB)		Correlation Coefficient(ρ) over day shown
	horizontal field component	vertical field component	horizontal field component	vertical field component	
Aug. 11	30.9	30.5	5.2	5.0	0.98
Aug. 12	27.0	26.4	3.7	4.1	0.97
Aug. 13	28.1	28.8	3.1	2.9	0.94
Aug. 14	29.6	29.0	6.9	6.9	0.98
Aug. 15	30.8	28.9	4.7	6.0	0.91
Aug. 18	28.2	27.1	5.0	4.4	0.95
Aug. 19	27.5	25.8	3.9	4.5	0.94
Aug. 20	29.2	28.3	3.4	3.3	0.98
Aug. 21	30.1	29.7	3.0	2.8	0.99
Aug. 23	25.0	25.2	2.9	3.0	0.92
Aug. 24	25.3	25.2	3.2	3.0	0.93
Aug. 25	21.6	21.9	2.4	2.4	0.89
Aug. 26	27.6	27.5	3.6	3.7	0.97
Aug. 27	30.2	29.9	2.0	2.3	0.88
Aug. 28	29.7	27.7	4.9	6.0	0.89
Aug. 29	26.1	26.7	3.1	3.8	0.93
Aug. 31	28.6	29.5	3.1	3.6	0.89
Sep. 01	28.1	27.5	2.3	2.8	0.85
Sep. 03	27.5	27.8	3.6	3.5	0.96
ENTIRE PERIOD	27.9	27.5	4.5	4.5	0.93

If, however the signal retains its original circularly polarised characteristics, the correlation coefficient will be +1, i.e. the amplitudes of the two signals will vary in the same sense, at the same time, while the phase difference remains unchanged. Under these conditions an increase in signal level will be provided by using a circularly polarised aerial, although this will give no change in the fading statistics.

In order that each of these dual component receiving systems may provide its greatest advantage, it is necessary that both components have similar mean signal levels. The normalised correlation coefficient merely relates the normalised amplitude variations over time between two components, which may have vastly different mean levels.

From the very high positive correlation coefficients apparent in Table 1, it would appear that the fading characteristics of horizontally and vertically polarised signals at v.h.f. over this particular path are almost identical.

Although no long-term measurements of the phase correlation of the two components have been made, it can be deduced that any variation will be small, thus the use of a circularly polarised receiving aerial is likely to result in an increase in signal level of up to 3 dB over a similar linearly polarised aerial. However, the 3 dB increase can also be obtained by doubling the aperture of the existing aerial receiving only one component. A circularly polarised aerial would thus provide substantially the same output signal level as two vertically polarised aerials or two horizontally polarised aerials; the only difference between the three systems being that the circularly polarised arrangement has less directivity than the others and is sensitive to polarisation variations in the propagation path. In a marginal re-broadcast link, greater aerial directivity is often beneficial to discriminate against unwanted signals from other co-channel stations. This would count against choosing circularly polarised reception.

6. CONCLUSIONS

It has been found that, for a circularly polarised v.h.f. signal travelling over a sea path of approximately 170 km, the propagation characteristics for the vertically polarised field component are almost identical to those for the horizontally polarised field component.

Under these conditions polarisation component diversity switching will offer no advantage over single component reception and increased signal level may be gained with greater advantage by using a larger aperture antenna receiving only one component.

7. REFERENCES

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